A Thermal Beam Position Monitor for the NuMI Target

NBI 2014
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September 24, 2014

Added a new device to the NUMI target for this run, which started Sept 2013

Goal

- monitor that proton beam stays centered on target within 0.5 mm

Philosophy

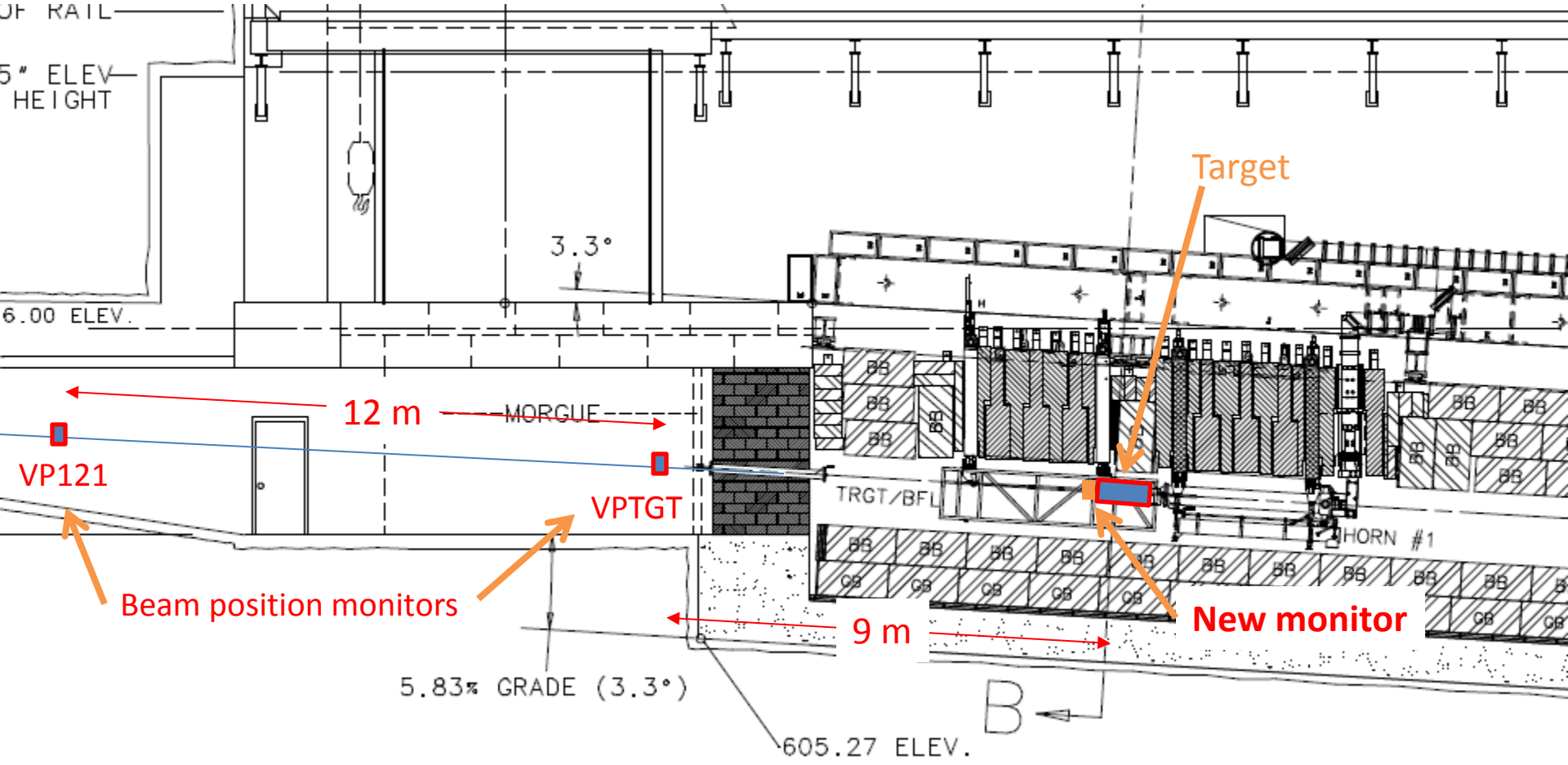
- Keep it simple
- Make it robust

Constraints

- Hard to implement new utility lines through target support module
- Harsh environment (radiation, corrosive air)

What niche does this device fill ?

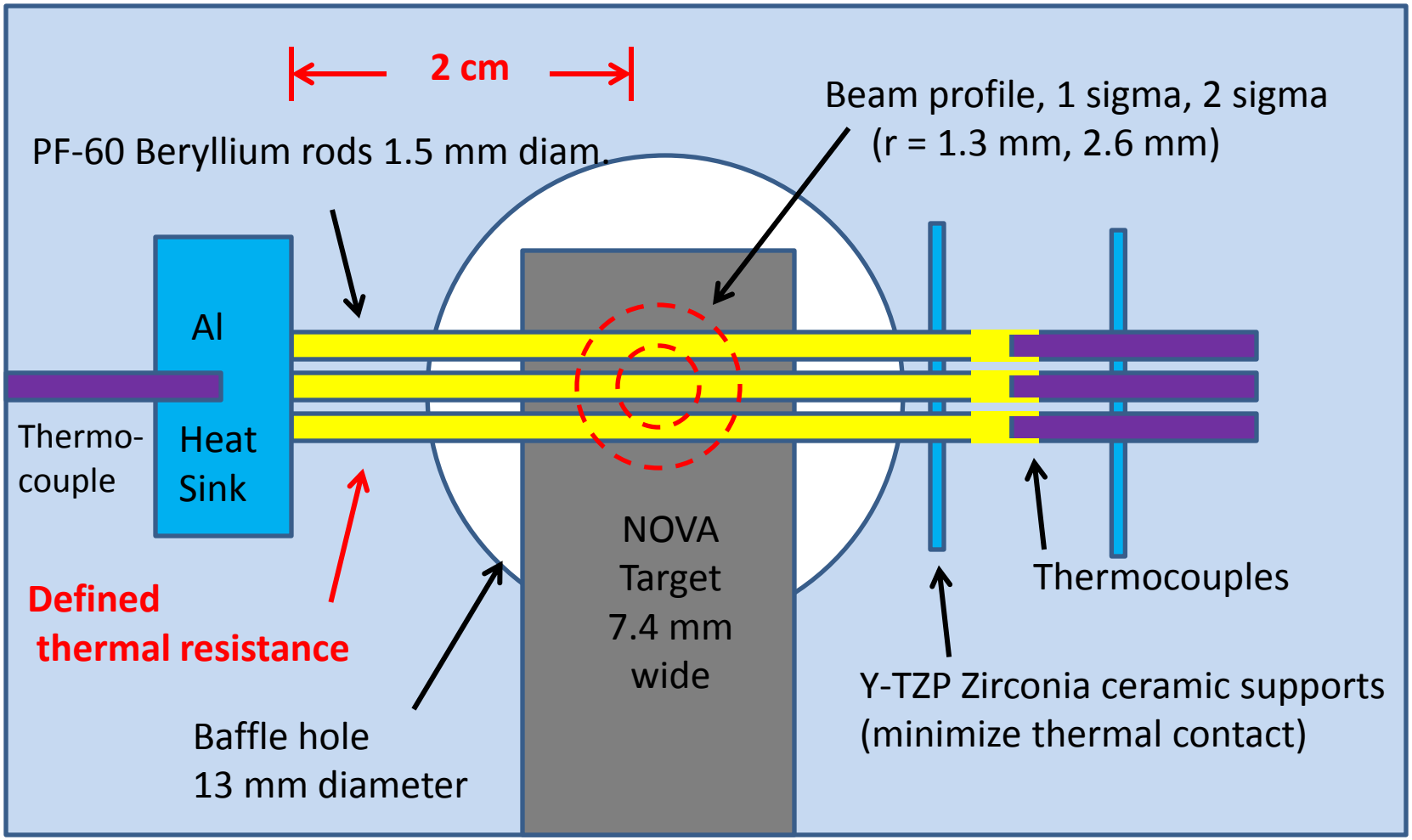
- Last proton beam line position and profile monitors are **9** m upstream of target
- Alignment condition previously set by low intensity beam scan across symmetrical target (But new NOVA target is no longer vertically symmetric)
- Misalignment during running can be roughly detected by muon yield 700 m downstream, but beam position is only one of several things that can cause muon system response to change
- This device checks that the beam is centered on target during high intensity running


Target
12 m
MORGUE
VP121
VPTGT
TRGT/BFL
HORN #1
Beam position monitors
New monitor
9 m
5.83% GRADE (3.3°)
605.27 ELEV.
3.3°
6.00 ELEV.
B

Thermal Beam Position Monitor

Beryllium rods, near upstream window of target, to watch beam position

(not to scale; also baffle drawn behind target, although it is actually in front)



Principle of operation

ΔT (Rod – Sink) α (beam power deposition in rod) *times* (thermal resistance)

Beam position derived from ratio of ΔT's of the different rods

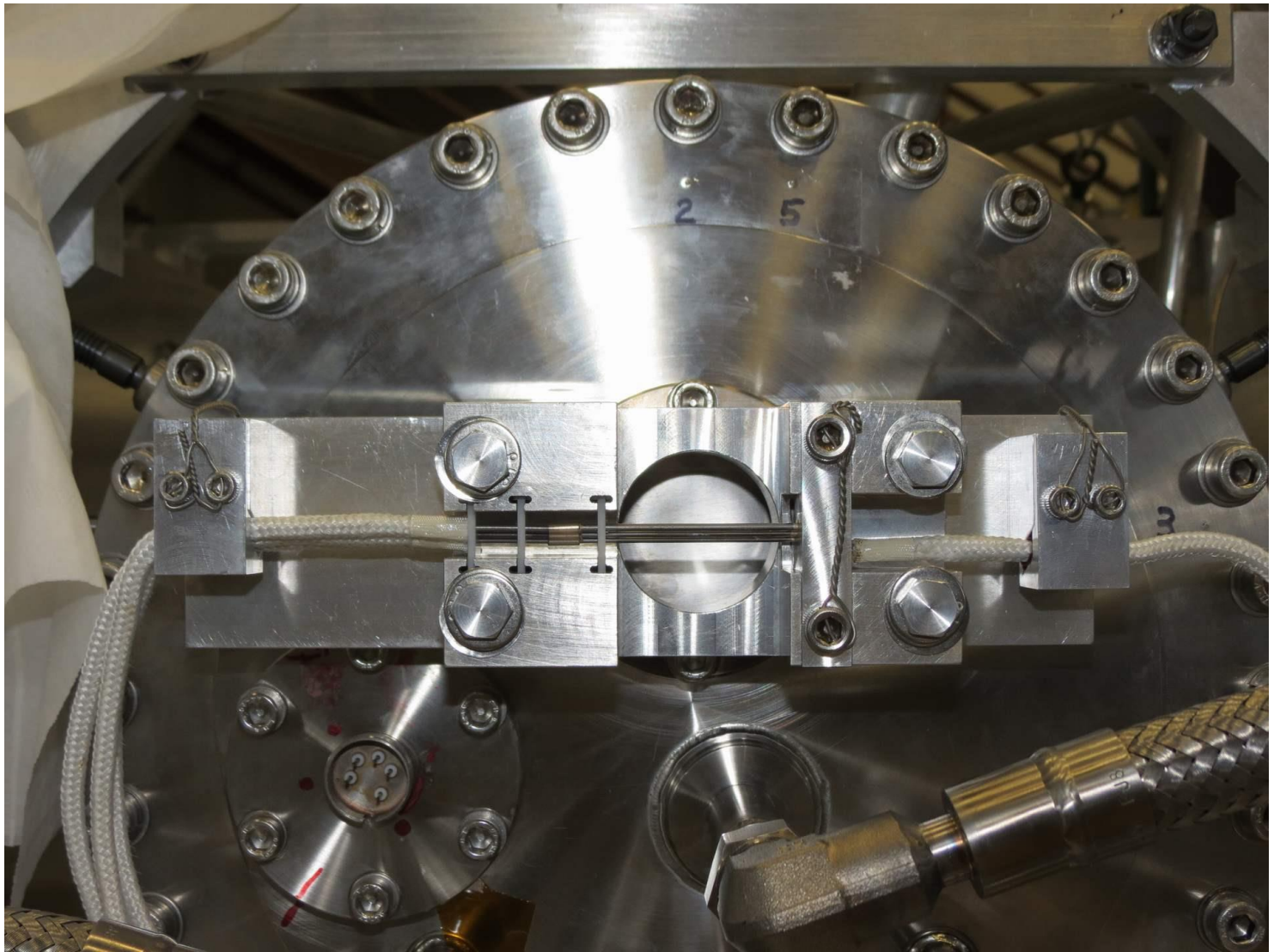
(can think of it as a rather sparse profile monitor)

At NuMI upgrade 700 kW design beam power120 GeV protons

- 1.333 seconds Beam cycle time
- 4.9e13 POT/spill
- 1.3 mm beam spot size RMS

Expect ~ 0.9 watts deposited in rod centered in beam

Beams-eye view of thermal beam position monitor mounted on NuMI target MET-01



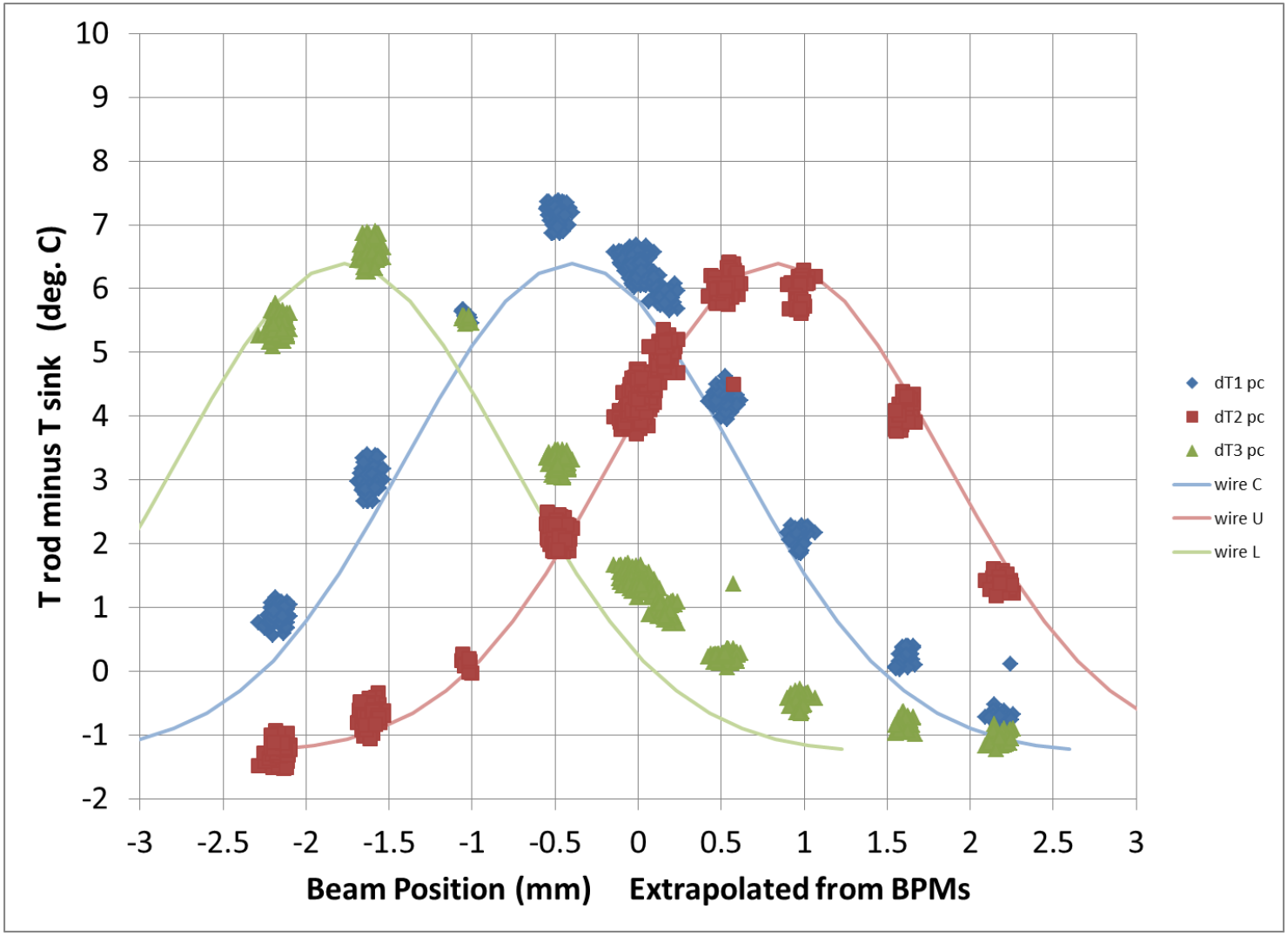
CONs:

- Not a single pulse device, use with stable beam
  - characteristic time scale ~ 9 seconds; want ~ minute to get really stable
- Needs a couple deg. dT to provide measurement, limited to < 200 deg.
  - Limited beam power range, not a low intensity tune-up device

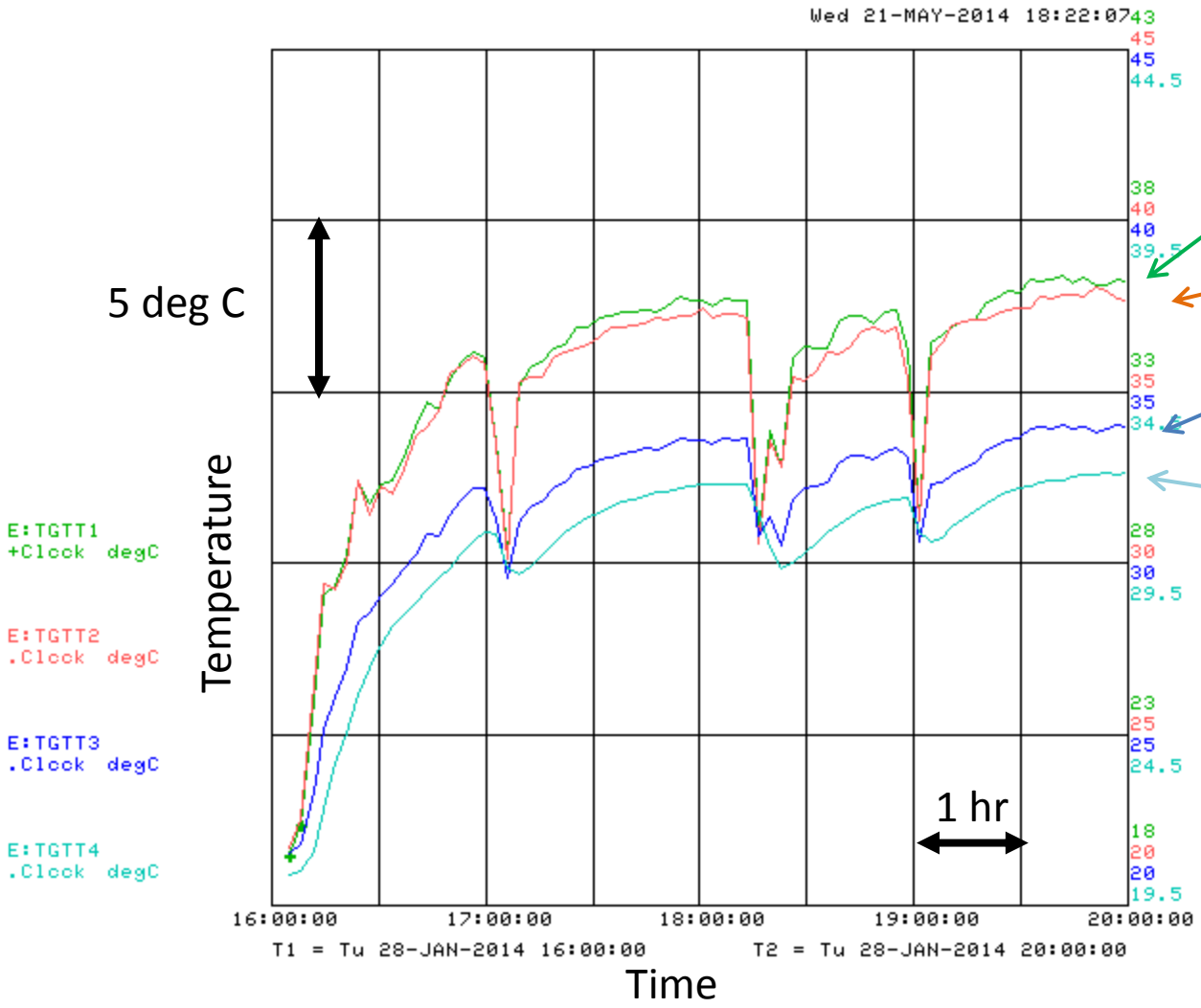
PROs:

- Simple, robust – *should be able to take anything the target window can take*
- Radiation hard
- Depends on a bulk volume phenomenon
  - *Surface degradation doesn't matter*
- Readout can be off-time of beam pulse
  - *Immune to noise pick-up, stray charge*
- Minimal utilities (*no vacuum, no gas, no water, no windows,* …)
- Can calibrate in-place *scan beam across rods*
  - Peak temperature when beam is pointed at rod
    (*no "electronic center" to be pre-calibrated as in a BPM*)
  - Simultaneously see ΔT ratios of the rods
- No maintenance

Results of a beam scan (in situ calibration)



Sample response after beam start-up



Central rod

Top rod

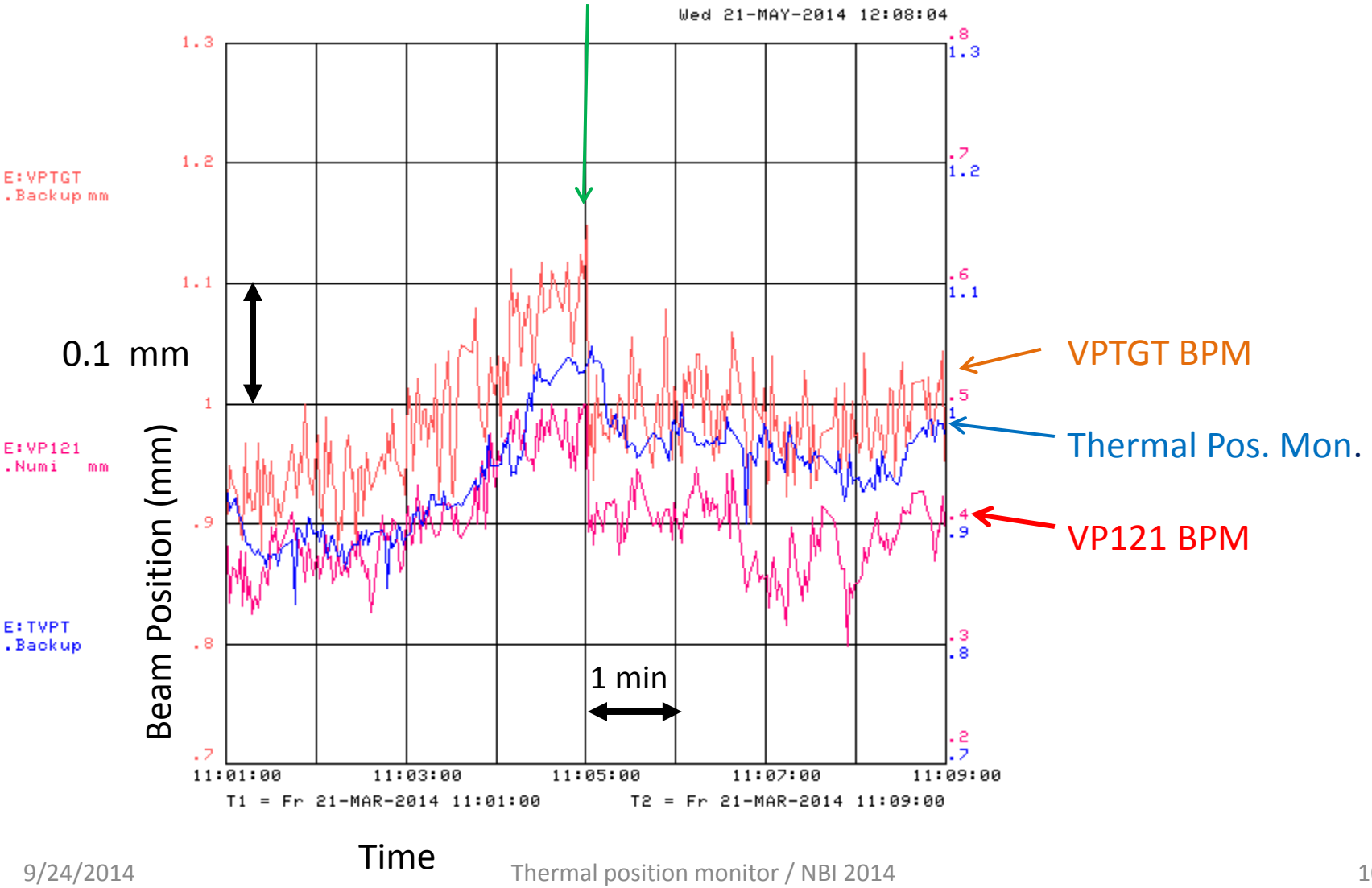
Bottom rod

Sink

Would be nicer if sink were cooled, but still works fine

Sample short time response

Beam drifting, AUTOTUNE program makes 0.1 mm adjustment,
takes Thermal Position Monitor a fraction of a minute to follow



- This first device already proved very useful, aiding in diagnostics when the calibration of one of the BPMs was drifting last fall.
- More than 3e20 POT, 0.2 MW-yr of beam so far, no sign of any degradation
- Resolution and stability is below 0.1 mm; think it likely will work even better at higher beam power (thermocouple pedestal and temperature resolution should have less effect)
- This target has only vertical monitor; will put both Vertical and Horizontal thermal monitors on the next target

Conclusion

Robust device that tracks position of beam at target at high intensity

Provides position resolution at the target comparable to our BPMs